=78-0523-

Quarterly R&D Status Report PSR-1046-78-6
Contract MDA903-77-C-0184
ARPA Order No. 3344
Report Period 1 February, 1978
to 1 May, 1978
Report Date June 1, 1978

AD-A134987

AN INTERACTIVE COMPUTER AIDING SYSTEM FOR GROUP DECISION MAKING

RANDALL STEEB
ANTONIO LEAL
STEVEN LEVIN

Prepared For:

Cybernetics Technology Office
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 Wilson Boulevard
Arlington, Virginia 22209

PERCEPTRONICS
6271 VARIEL AVENUE • WOODLAND HILLS • CALIFORNIA 91367 • PHONE (213) 884-7470

NOTES

Quarterly R&D Status Report PSR-1046-78-6
Contract MDA903-77-C-0184
ARPA Order No. 3344
Report Period 1 February, 1978
to 1 May, 1978
Report Date June 1, 1978

AN INTERACTIVE COMPUTER AIDING SYSTEM FOR GROUP DECISION MAKING

RANDALL STEEB
ANTONIO LEAL
STEVEN LEVIN

Prepared For:

Cybernetics Technology Office
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
1400 Wilson Boulevard
Arlington, Virginia 22209

PERCEPTRONICS
6271 VARIEL AVENUE • WOODLAND HILLS • CALIFORNIA 91367 • PHONE (213) 884-7470

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: PQTR-1046-78-6
2. GOVT ACCESSION NO.: A134 987
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): AN INTERACTIVE COMPUTER AIDING SYSTEM FOR GROUP DECISION MAKING
5. TYPE OF REPORT & PERIOD COVERED: TECHNICAL REPORT
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s):
Antonio Leal
Steven Levin
Randall Steeb
8. CONTRACT OR GRANT NUMBER(s): MDA903-77-C-0184
9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Perceptronics Inc.
6271 Variel Avenue
Woodland Hills, CA 91367
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: ARPA Order No. 3344
11. CONTROLLING OFFICE NAME AND ADDRESS:
DARPA - Cybernetics Technology Office
1400 Wilson Boulevard
Arlington, VA 22209
12. REPORT DATE: June 1978
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report):

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:

Approved by: ____________

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Group Decision Aiding
Decision Trees
Utility Conflict Resolution
Utility Aggregation
Sensitivity Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a program centered on the demonstration of an interactive computer aid for Group Decision Making. The report includes: (1) descriptions of technical improvements planned for the system, (2) plans for experimental evaluation of system effectiveness, and (3) descriptions of a cooperative system planning application for NADC. The next phase of the program will concentrate on the design, implementation, and testing of the system improvements and extensions.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

1. SUMMARY

1.1 Report Period

The fifth quarter of contract activity involved: (1) implementation of changes identified during the initial test and evaluation experiments, (2) specification of technical improvements and extensions for the Group Decision Aid, (3) definition of a cooperative effort with NADC to apply the aid to systems planning decisions, and (4) specification of experimental procedures for evaluation of the Group Aid. The following specific tasks were completed during the report period.

(1) A series of changes were completed following the test and evaluation experiments. Included were (1) consistency checks on probability inputs, (2) correction procedures for value changes by participants, (3) designs for decision tree regeneration, and (4) provision for audit trail time information.

(2) Possible extensions and improvements to the group decision system were reviewed for the period from the present to October 1, 1978. A set of high priority tasks were selected for implementation, dealing with scale definition, attribute weighting, additional sensitivity and conflict analyses, and new procedural options. Tasks planned for the period following October 1978 were also detailed.

(3) A cooperative effort with the F-14 program office of NADC was established. The program office is planning to use the Group Aid for problems of design decisions, procurement, task scheduling, and other areas of systems planning.

(4) Plans for experimental evaluation of the group decision aid were developed in cooperation with CACI. Task scenarios using both the terrorist crisis and NADC systems planning problems were included. Measures describing group participation, decision development, conflict resolution, and decision quality were detailed.

1.2 Next Period

The contract period during the next quarter will primarily concentrate on implementation of program improvements and extensions. Informal evaluations of these improvements will then be made, along with finalization of plans for a full-scale system evaluation. The specific items of work for the next period include:

(1) Design, implement, and test system improvements and extensions.

(2) Evaluate system changes using informal experimental studies and prepare for full-scale experimental studies.

(3) Continue cooperative effort with NADC to develop system design application.

1.3 Program Milestones

The milestone chart for the contract program is shown in Figure 1-1, with the report period illustrated as the checkered portion.

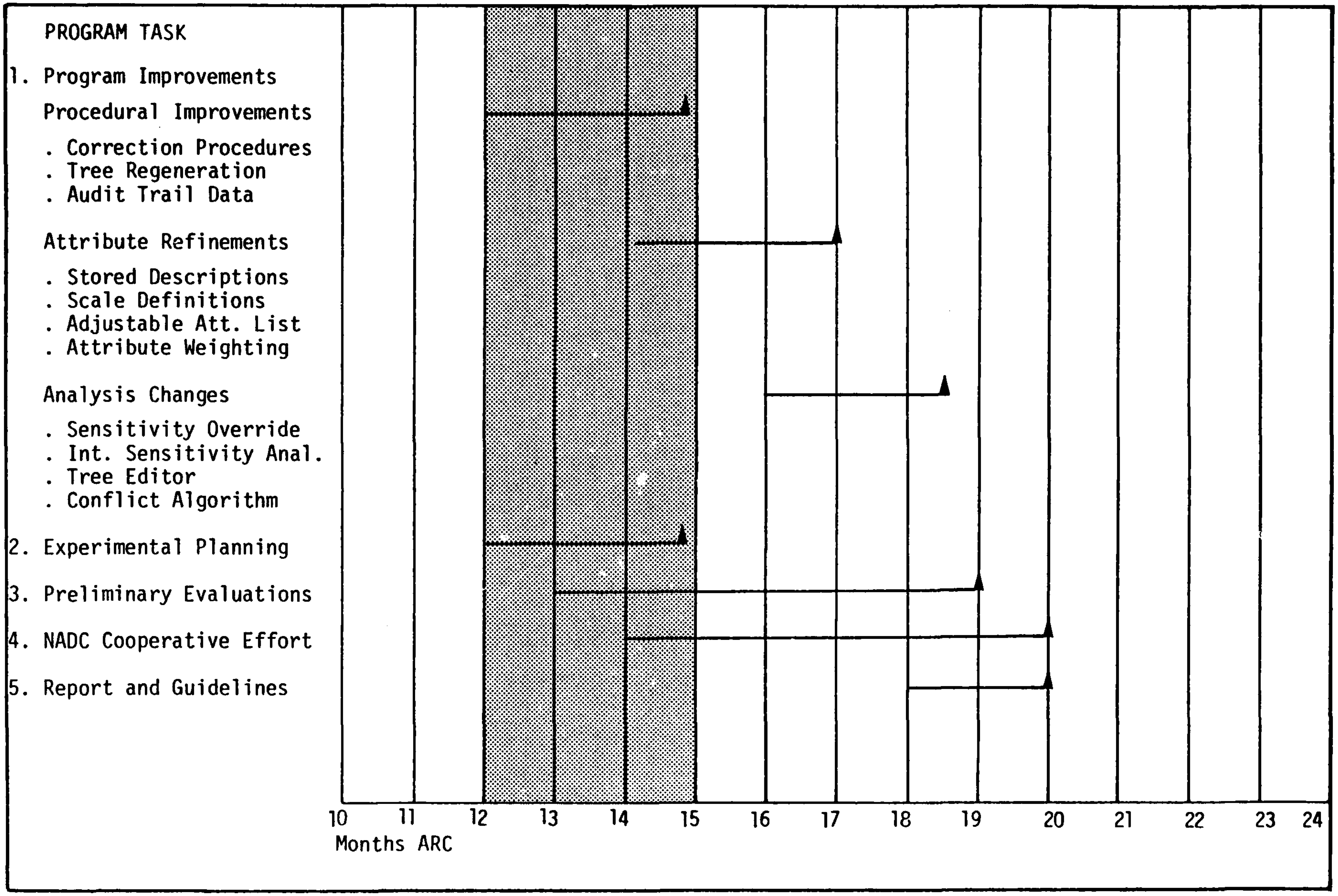

TABLE PROGRAM MILESTONES

1.4 Report Organization

Chapter 2 is a program overview containing the problem statement, program rationale, and program objectives. Chapter 3 describes the program improvements and extensions. Chapter 4 is an analysis of the planned cooperative effort with NADC. Chapter 5 describes plans for experimental evaluation of the Group Decision Aid.

2. PROGRAM OVERVIEW

2.1 Statement of Problem

Constant escalation in weapons cost and effectiveness, as well as the increasing complexity of international relations, makes military decision making more critical today than ever before. In today's military environment, most upper-level decisions are made by committees and staff groups. Typically, such groups contain experts from several speciality areas, who bring to the decision environment disparate sets of values. Decision time is usually limited, the decision making procedure is relatively unstructured, and intragroup conflicts arise on a broad variety of issues. Consequently the group is unable to consider the maximum set of alternatives, conflicts are not resolved in an optimum manner, and the resultant decision is rarely up to the aggregate potential of the group membership.

2.2 Rationale

Decision analysis offers a promising approach to solving these problems. The analytical procedure of building a decision tree formalizes the decision process, and permits incorporation of individual values (utilities) into the selection of alternative courses of action (Hays, O'Connor, and Peterson, 1975). However, decision analysis as it is usually practiced, is a highly personal and time-consuming process. Decision analysts are often called upon to assist in the solution of problems ranging over a large variety of domains. In most cases, the decision analysts know far less about the problem domain than do their clients. Thus their contributions are confined primarily to the phases of formalization and optimization. While optimization is usually computer assisted, the formalization phase invariably has been accomplished manually, using lengthy interviews of persons more familiar with the

problem area. This approach is generally incompatible with the conditions of command group decision making.

Accordingly, it would be highly worthwhile to automate the formalization phase, using an interactive computer system to interrogate the group members and to construct a decision tree based on their responses. The purpose of the research undertaken here is to develop and evaluate the means by which such an interactive aid could be used to improve group decision making.

2.3 Objectives

The goal of the research program addressed in this progress report is to develop an automated decision tree elicitation system, using on-line sensitivity analysis with direct real-time group feedback and evaluate its effectiveness in aiding group decision making.

The specific objectives of the current program include the following:

(1) Develop computer programs for efficient, comprehensive, elicitation of decision trees from a decision making group.

(2) Develop computer programs for identifying structural and numerical differences among the contributions of individual group members, for merging these contributions and for resolving the points of conflict.

(3) Develop effective means for displaying to the group the results of the elicitation procedures and conflict analyses.

(4) Integrate the various programs and techniques into a complete aiding system which can be readily transferred to other test environments.

(5) Experimentally test the Group Decision Aid, using a variety of representative military decision problems, to demonstrate its advantages under realistic conditions of use.

(6) On the basis of the developmental effort and the experimental results, establish guidelines and recommendations for future military applications of the group decision aiding methodology.

3. SYSTEM IMPROVEMENTS

3.1 General

The initial system tests, described in our recent technical report (Leal, et al, 1978), were highly successful. The initial development goals of the system were realized, in that experienced groups were able to work effectively with the aid toward the solution of a realistic and representative decision problem. At the same time, a number of system areas were identified in which existing features could be modified, or new features added, in order to improve overall system performance and power. Suggestions for candidate improvements came (1) from our review of original system goals; (2) from our review of related developments in computerized decision aiding, such as the IBM 5100 aiding packages produced for ARPA/CTO by DDI; (3) from suggestions made by knowledgeable visitors to whom the system was demonstrated, such as Dr. Clinton Kelly, of DDI; Dr. Martin Tolcott of ONR; Dr. Ward Edwards of USC, and others; and (4) from suggestions made by our ARPA monitors and other ARPA personnel.

The selection and ordering of the improvements were derived by evaluating potential tasks with respect to six attributes: (1) effect on decision theoretical fidelity, (2) effect on acceptability, (3) effect on resources, (4) effect on group processes, (5) effect on decision quality, and (6) effect on decision time. Analysis showed that a number of the improvements could be scheduled for development during the FY 78 program period, i.e., by September 30, 1978. Others, requiring a greater expenditure of effort, are planned for the following period. Both sets of improvements are described in the following sections.

3.2 Technical Improvements

The following extensions to the Group Decision Aid are planned to be completed by October 1, 1978. These tasks will greatly enhance the decision-theoretic fidelity of the system as well as prepare it for formal evaluations. The tasks are listed in order from easiest to hardest to implement.

Stored Descriptions. It is sometimes difficult to capture complex alternatives or outcome situations with a few words (currently ten letters for tree descriptions). A small amount of time should be used by the group to develop detailed definitions and descriptions of each major alternative, event, and attribute. The descriptions may be displayed at any time for reference. The description may include such items as the actor, the action, the recipient, the situation, and the time frame. An example of an action description follows:

> Display strength: Deploy carriers immediately to Mandero City and await response.

Scale Definitions. It is critical to define clearly the endpoints and properties of the utility scales. The scales of both the attributes and the action/event nodes must be defined consistently. Each attribute will be scaled by defining the worst possible level to be zero and the best possible to be 100. Shortened labels should be assigned at each of these endpoints and, optionally, at the midpoint of the scale. Quantitative definitions, such as dollars or reliability indices, should be used whenever possible. An example scale for the attribute of cost follows:

$100 million Loss	$60 million Loss	$20 million Loss
0	50	100

The overall utilities of actions or events must be defined along a single, common scale, established early in the analysis. Again, the zero point will correspond to the worst possible state, while the 100 point will denote the best possible state. At the same time, consistency will be maintained by having the upper and lower endpoints correspond to all zeros and all 100s on the individual attributes, respectively. Key points along the scale (such as the 25, 50, and 75 points) will be described by explicitly defined states.

Adjustable Attribute List. Where conflicts arise, the group must assign levels to the established attributes of the particular alternative in conflict. The construction of the attribute list is the first task the group must perform. However, it is very difficult to foresee the applicability of the attributes to particular future alternatives or outcomes. An adjustable attribute list is required to allow new attributes to be added and to allow irrelevant ones to be deleted.

For the most part, the attribute set should be invariant with respect to the alternatives. This is because the attribute membership derives from the set of objectives characterizing the problem, and not from the choices present. However, development of the decision tree may bring to light additional considerations which should be included as attributes. For ease of comparability across actions, such changes must be incorporated in previously evaluated nodes.

Attribute Weighting. It is unlikely that the attributes will all be equally important with respect to the particular alternative in conflict. A number of researchers (Newman, Seaver, and Edwards, 1976; McClelland, 1978) have shown that differential weighting (distinct weights for each attribute) is important in most real-world situations. The evaluation

function will then take the following form:

$$U_j = \sum_i w_i A_{ij}$$

where U_j is the overall utility of outcome j

w_i is the importance weight of attribute i

A_{ij} is the level of attribute i occurring with outcome j

The weights w_i define the policy of the decision maker with regard to the different dimensions of outcome. This policy should be invariant with respect to the possible alternatives. The attribute levels, on the other hand, characterize the choices or outcomes along the dimensions, costs, tactical gains, political impact, etc. As such, these levels vary with each choice and must be estimated for each point in conflict.

The importance weights will be elicited from each participant after definition of the set of attributes. The elicitation process is patterned after that used by DDI (Selvidge, 1976) and by SSRI (Gardiner and Edwards, 1975). In short, comparisons will be made of the importance of swings across the range of each attribute. The first attribute will arbitrarily be given a weight of ten points. Each remaining attribute will be compared to the first attribute by estimating the importance of a change from the lowest to highest level compared to a change from lowest to highest on the first attribute. For example, if a swing across the range of the first attribute, a weight of 20 will be assigned. Once all of the attributes are thus weighted, a normalization is made: each attribute is set equal to its raw weight divided by the sum of raw weights and multiplied by 100. This results in a normalization where the sum of all weights equals 100 points.

The above procedures will result in a set of weights for each participant. No attempt will be made to resolve completely the individual differences in weighting, as these differences may reflect actual conflicts in policy between the participants. The individual weights will be carried through the tree development and conflict resolution processes. In this way, conflicts due to individual policy can be distinguished from conflicts due to differences in probability or attribute level estimation.

It was noted earlier that membership of the attribute set should be invariant with respect to the part of the tree under development. Similarly, the weighting of the attributes should be the same across the tree. However, if new attributes are defined or old ones deleted, the alternative weighting will have to be altered. If any attribute is deleted, the remaining weights can be renormalized directly. If an attribute is added, a new set of weights must be elicited and renormalized.

Sensitivity Analysis Override. It may be counterproductive to be forced to expand the particular node "recommended" by the sensitivity analysis algorithm. The group should be able to override this recommendation and choose any node to expand. This feature would be very helpful during demonstrations and filming where canned sceanarios are used. Much of the software for this feature has already been implemented in the form of a tree traverser, by which attention may be directed to any node. Also, it may be helpful to display the second choice recommended by the sensitivity analysis program. This information will be provided to the intermediator.

Interactive Sensitivity Analysis. Sensitivity analysis has many more uses than simply recommending the next node for expansion. For example, probabilities and utilities can be varied across their possible ranges to determine their effect on the original decision. Attribute

levels and weights can similarly be automatically varied to see if they have an actual impact on the decision. In this way, attention can be shifted from considerations of minor importance to factors that are critical to the decision. The sensitivity analysis can be displayed graphically or by showing critical points of the parameters. The group members should be able to request such sensitivity modules to be exercised by the intermediator. Recent work has been done in this area by DDI which will form the basis for development.

Tree Editor. It is unrealistic to expect the group to be able to develop a decision tree without error the first time. Alternatives will be forgotten; events will be found too improbable to be included; formally closed branches will be reopened, etc. A tree restructuring capability will permit groups to alter previously built portions of the tree at any time. This capability will greatly enhance the quality of the final tree.

New Conflict Resolution Algorithm. The current conflict identification and resolution algorithm is somewhat arbitrary in the sense that there is only an indirect relationship between differences in values and differences in preferred actions. For example, it is possible to have large differences in opinion as to the value of an event, but agreement on the initial decision (at the root of the tree). A new algorithm will identify conflicts only as those differences of . values that cause a difference in the initial decision. The sensitivity analysis program will test each participant's values, one at a time. This new conflict resolution algorithm will probably be employed less frequently. However, when it is used, it will deal with "true" conflicts.

3.3 Deferred Improvements

The following extensions are planned for the period subsequent to October 1, 1978. These tasks incorporate many required changes and

additions to the Group Decision in order to produce a complete and integrated system.

Prior Information Display. It is vital to keep the group consistently informed about their progress. This information includes the current region of the decision tree under discussion as well as previous utility and probability assignments. This information must be displayed during each elicitation phase and not just at the end of each decision cycle. Methods for compact and comprehensive information display must be developed.

Conflict Resolution Algorithm. A classification of conflict with respect to source (utilities, probabilities, or attributes), will be helpful toward resolving the conflict. This is planned to be accomplished by allowing each source to vary while holding the outer sources constant (setting the other sources to their average across the participants). Then if a conflict is present, it is due to the source allowed to vary.

Utility and Probability Aggregation Formulas. An analysis of alternative utility and probability aggregation formulas will provide a basis for adopting new formulas or a justification for retaining averaging methods.

N-Level MAUM. With a modest amount of implementation effort, the conflict resolution module containing the Multi-Attribute Utility Model (MAUM) can be made hierarchial in the sense that individual attributes can be decomposed into sub-attributes when in conflict.

Action/Event Matrices. In cases where a series of events all apply equally to a series of possible alternatives, a matrix representation of utilities and probabilities may be more efficient

than a decision tree for estimation. DDI has developed elicitation techniques for such matrices and their implementation could increase the efficiency and quality of the aid.

Elicitation Aids. The actual assignment of utilities and probabilities can be enhanced by the use of various previously developed techniques that require the decision maker to analyze the assessment in detail. Such techniques utilize internal comparisons and validity checks in an attempt to obtain the best estimate possible. Although the aids usually result in a more accurate assessment, they take a considerable amount of time to execute. Their use should be limited to particularly difficult estimation situations. DDI has developed some elicitation aids which could be employed.

Influence Diagrams. The decision tree is applicable only to decision problems that can be expressed in terms of actions, counter-actions, and probabilistic events. There is no method for representing influences, causes, and dependencies. New networks called "Influence Diagrams" can be added to the system to allow a wider range of decision problems to be accommodated.

3.4 Bayesian Probability Aiding

For probability estimates, the currently configured system uses direct estimation along a 0-100 scale. This method is simple and effective in single-datum situations without extreme probabilities, but may lead to serious inaccuracies in more complex circumstances. A number of aiding systems, beginning with Edwards (1962, 1964) and more recently demonstrated by CACI and DDI, use Bayes' theorem to help the decision maker optimally revise his opinion in the light of new information. The technique allocates data evaluation to the man and

data aggregation to the computer. The concept requires that the person estimate conditional probabilities that specific data will be observed when certain outcomes occur, and then transmit these to the computer, which utilizes Bayes' theorem to aggregate the likelihood estimates and make new estimates. By following this procedure, it is possible to compensate for man's inability to retain and combine separate data points to an overall conclusion. Perceptronics has, in fact, developed such a system for hand-held combat input of multiple likelihood estimates (Ben-Bassat, 1978).

Use of a Bayesian probability aiding program would provide two functions: (1) it would result in more accurate estimation of complex probabilities, and (2) availability of likelihood estimate input would provide a valuable check on the simple linear scale probability inputs. For these reasons, it is planned to incorporate a currently operational Bayesian module (either DDI or CACI) with the Group Decision Aid. Feasibility studies of each system will be conducted during the current contract period, and implementation is planned to take place during the coming program.

4. SYSTEMS PLANNING APPLICATION

Several meetings have taken place with personnel of the F-14 program office of NADC toward use of the group decision aiding system for systems planning. The program office is highly enthusiastic about applying the aid to problems of design decisions, procurement, task scheduling, and other areas of system planning. Such expansions of application areas would provide ample opportunities for extensive evaluation of the usefulness of the aid.

A typical planning problem is shown in Figure 3-1. This decision tree is representative of the types of problems that would be encountered in a procurement decision situation. The initial decision node shows the problem of replacement of an Inertial Measurement Unit (IMU) in a future aircraft by either (1) buying an outside custom-made unit, (2) buying an existing unit, or (3) modifying existing equipment. The various branches show actions and events as they may be developed by the group.

The area of Systems Planning and Design Decision has some important differences from that of Antierrorist Actions. The clearest distinction is the atmosphere of urgency that is present in Anti-Terrorist decision making but is not in systems planning. Crisis management decisions are made in hours while system planning decisions usually occupy days or even weeks. This means that there is opportunity to develop a larger and more detailed tree with many more possibilities of altering previously constructed portions. The "tree editor" then becomes a more important component of the system. Further, there is time to receive new information from the outside and incorporate it into judgmental values - a situation that has assumed not to exist in previous anti-terrorist scenarios. A program that calculates the cost of obtaining new information and its impact on the decision tree would be very beneficial. Since many decisions

from system planning deal with real monetary costs, a value scale based on dollars instead of utility may be desirable. This would provide a basis to compare the value of various situations more accurately.

The opportunity to store specific information about the problem domain is enhanced when dealing with systems planning. Design and procurement decision making is more objective than anti-terrorist decision making, and thus would provide a basis for a more exact formulation of previous experience. The formation of a domain-specific data base for use with the Group Decision Aid would be not only more straightforward, but also easier to access and use.

The effect of systems planning applications on experimental evaluation is enormous. With a genuine interest on the part of NADC to incorporate the Group Decision Aid into operational design procedures, the opportunity exists to compare the results of using the aid with (1) the documented outcomes of previous decisions, and (2) the current decision-making practices at NADC. Such an environment provides a "ground truth" with which to establish objective group decision improvement measures - an opportunity that did not exist in anti-terrorist decision making.

5. SYSTEM EVALUATION PREPARATIONS

5.1 Overview

A plan for comprehensive evaluation of the group decision aid has been developed in cooperation with CACI. The evaluation will be directed toward the following major objectives:

(1) Determine the specific contributions to problem definition, conflict resolution, and decision quality provided by the group decision aid.

(2) Aid in development of additional system capabilities.

(3) Determine the domain of application of the system.

(4) Aid in production of system specifications and guidelines for operation.

These objectives are planned to be accomplished through an experimental program based on comparisons of aided and unaided group performance in several different task scenarios. The following sections describe the preparations for this evaluation.

5.2 Task Scenarios

Two types of scenarios are planned for evaluation of the group aid. The first is the currently used crisis scenario based on counter-terrorist actions. The CACI-developed scenario has plausibility, reasonable complexity, and exhibits a number of significant judgmental issues triggering intra-group conflict (CACI, 1978). It has also been the

subject of extensive analysis, providing baselines for analysis of group behavior. As such, it represents an ideal vehicle for controlled experimentation. The second scenario is the NADC systems planning design problems described earlier. This scenario differes from the terrorist situation by concentrating on monetary consdierations and technological development problems. Also, it involves deliberations of NADC personnel on actual military problems. The NADC technical design scenario has not been developed to the level of the terrorist scenario, but should provide a useful auxiliary testbed for informal studies.

5.3 Performance Measures

A variety of objective and subjective measures will be used to evaluate the effectiveness of the group decision aid. The measures have been refined to arrive at operational procedures and practical worksheets by CACI (1978). These measures fall into four main categories: group participation, decision development, conflict resolution, and decision quality. Each of these measures will be discussed in detail.

Group Participation Measures. A major goal of the group aid is to increase the level of participation in the decision making process. The degree of participation is reflected in the following measures:

(1) Sturctural inputs - the number of alternatives, events, and attributes submitted by each member.

(2) Voting deliberations - the number of decision makers participating in deliberations about probabilities and attribute levels.

(3) Temporal participation - the amount of time each decision maker contributes to discussion.

For the most part, these measures will be taken from recordings of deliberations. Audio or video tape media will provide the data.

Decision Development Measures. These measures evaluate the degree of development of the group decision output. They tend to be observable and easily qualifiable.

(1) Tree complexity - the number of nodes, the average number of branches emanating from each node, and the depth of tree in number of levels.

(2) Information used - the completeness of use of the information available to the participants. The terrorist scenario has been analyzed by experts at CACI, developing a checklist of critical items of information that impact the occasion. This checklist, the content analysis dictionary, will be employed to measure the completeness of information use.

(3) Time expenditures - the time spent in each of the activities of decision structuring. This task analysis will time the activities of information search, data incorporation, discussion of objectives, synthesizing alternatives, identifying possible events, and discussing adversary capabilities. Additional non-group activities of prompting by the intermediator and inputting of data into terminals will also be logged. Finally, the overall time for completion of decision structuring will be recorded.

Conflict Resolution. The degree of resolution of conflict through use of the group aid can be determiend using the following measures:

(1) Degree of change after discussion of utility, probability, and attribute differences among members.

(2) Degree of change in action evaluations among members after discussion.

Decision Quality. The final determinant of the usefulness of a group decision aid is the quality of the decisions provided. While there is seldom a single "correct" solution to the complex judgmental problem faced by the groups, a number subjective and quasi-objective indicators of decision quality can be incorporated.

(1) Structural content - a comparison, node-by-node, of the tree structure and parameter estimates with a "school solution". The school solution will be generated by expert personnel.

(2) Information content - the decision tree will be coded according to the degree of consideration of a set of key aspects regarding the scenario. CACI has prepared such a set for the terrorist scenario in the form of a "quality assessment score sheet". An overall evaluation then results from an aggregation of the coded scores.

(3) Subjective measures - subjective ratings will be recorded with respect to decision aid performance in the areas of information usage, alternative generation, deliberation, evaluation, choice selection, and implementation.

Taken individually, the above catalog of measures describes the specific contributions of the group decision aid. The measures are planned to be used for revision and refinement of the aid and for specification of the

domain of application. An overall evaluation of system effectiveness is more difficult. It appears that such an evaluation would be facilitated using a multi-attribute scheme, much like that employed by the aid itself. The four areas of measurement and their associated indices form a hierarchical evaluation function. Each type of measurement thus represents a separate attribute. Weighting and aggregation of these attributes according to the objectives of the task situation then provide an overall evaluation.

6. REFERENCES

Ben-Bassat, M. Computer-Aided Situation Assessment: Technology Requirements. Perceptronics, Inc. (Woodland Hills, CA) Internal Memo, Contract DAHC19-77-C-0097, 23 February, 1978.

C.A.C.I. Further Development of Evaluation Methodologies for an Interactive Computer-based Group Decision Making Aid. CACI, Inc. (Arlington, Virginia) Final Report, June 1978.

Edwards, W. Dynamic Decision Theory and Probabilistic Information Processing. Human Factors, 1962, 4:59-74.

Edwards, W. Man as Transducer for Probabilities in Bayesian Command and Control Systems. In Shelly, M.W. and Bryan. G.L. (EDS.) Human Judgment and Optimality. New York: Wiley, 1964.

Gardiner, P.C. & Edwards, W. Public Values: Multi-Attribute Utility Measurement for Social Decision Making. In Schwartz & Kaplan (Eds.), Human Judgment and Decision Processes: Formal and Mathematical Approaches. New York: Academic Press, Inc., 1975.

Leal, A., Levin, S., Johnston, S., Agmon, M., and Weltman, G. An Interactive Computer Aiding System for Group Decision Making. Perceptronics, Inc. (Woodland Hills, CA) Technical Report PQTR-1046-78-2, February 1978.

McClelland, Gary H. Equal Versus Differential Weighting for Multi-Attribute Decisions: There are no Free Lunches. University of Colorado Institute of Behavioral Sciences, Technical Report No. 207, 1978.

Newman, J., Seaver, D.A., and Edwards, W. Unit Versus Differential Schemes for Decision Making. Social Science Research Institute (Los Angeles, CA) Technical Report 001597-2-T, July 1976.

Selvidge, J. Rapid Screening of Decision Options. Decisions and Designs, Inc. (McLean, VA) Technical Report TR76-12, 1976.